

NSW Threatened Species Scientific Committee

Conservation Assessment of *Carmichaelia exsul* F.Muell (Fabaceae)

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NSW Threatened Species Scientific Committee

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***Carmichaelia exsul* F.Muell (Fabaceae)**

Distribution: Endemic to Lord Howe Island, New South Wales (NSW)

Current EPBC Act Status: Not Listed

Current NSW BC Act Status: Endangered

Proposed listing on NSW BC Act and EPBC Act: Critically Endangered

Reason for change: Genuine change in extinction threat – increasing threat of habitat decline due to weed invasion and increasing hydrological deficit and landslip as a result of climate change.

Review of status was required as the current Endangered status was assigned under previous NSW legislation (*NSW Threatened Species Conservation Act 1995*) where the highest threat category available at the time of listing (2002) was Endangered.

Summary of Assessment

Carmichaelia exsul was found to be eligible for listing as Critically Endangered under Criterion B1ab(iii) and C2a(ii).

The main reasons for this listing are: 1) It has a very highly restricted geographic range (EOO is 16 km²); 2) The total number of mature individuals is extremely low (<250); 3) It is found at only a single location, scattered across a small area of ridgeline and cliffs in the Southern Mountains region of Lord Howe Island; and 4) There is inferred continuing decline in habitat quality as a consequence of increased hydrological deficit and landslip driven by climate change and ongoing weed invasion.

Description and Taxonomy

Carmichaelia exsul (Fabaceae) was first described by Mueller in 1871, and this classification is supported by Green (1994). A phylogenetic analysis of the genus conducted in 1998 supports the description of *C. exsul* at the species level (Heenan 1998). *Carmichaelia exsul* is the only species in the genus occurring in Australia, with all 23 other *Carmichaelia* species endemic to New Zealand (Green 1994, NSW Threatened Species Scientific Committee 2002, Wagstaff *et al* 1999).

Carmichaelia exsul is described by Green (1994) as ‘...a Broom-like shrub, 1-3 m tall. Adult shoots leafless, flattened, ridged, spreading and drooping. Leaves on juvenile shoots imparipinnate; leaflets 3-5, oblong to obovate, 0.7-2 (-3) cm long, 0.4-1.5 (-2.5) cm broad, apically rounded, emarginate. Inflorescence racemose, 2-5-flowered. Flowers white with purple markings, sweetly scented. Calyx somewhat obliquely campanulate, c. 2.5 mm long; teeth c. 0.5 mm long. Standard petal orbicular, 6-7 mm long; wings and keel c. 4-5 mm long. Pods ellipsoidal, flattened, 10-12 mm long, glabrous, with thickened margins; style persistent; dehiscing by two valves falling away leaving seed attached to replum. Seeds kidney-shaped, 3 mm long, pale orange.’

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Distribution and Abundance

Carmichaelia exsul is endemic to subtropical Lord Howe Island (NSW Government Office of Environment and Heritage 2017). Lord Howe Island (31.54°S, 159.08°E) is the largest of a collection of small volcanic islands in the Tasman Sea, 760 km northeast of Sydney (Department of Environment and Climate Change (NSW) 2007). The island is around 11 km long, and only 2.8 km at its widest point, with a total area of 1455 hectares and a maximum elevation of 875 m on its highest peak, Mt Gower (Department of Environment and Climate Change (NSW) 2007). The Lord Howe Island group was colonised by lineages of flora and fauna from mainland Australia, New Zealand and New Caledonia. This diversity of sources, combined with the island group's isolation, has led to the evolution of a high number of endemic species and unique ecosystems (Auld and Leishman 2015). There is a small town on the main island, however development and tourism are strictly controlled with 75% of the main island, and all other islands in the Lord Howe Island group, being under conservation management. The island group is UNESCO world heritage listed (Department of Environment and Climate Change (NSW) 2007).

Carmichaelia exsul is restricted to the Southern Mountains region of Lord Howe Island, encompassing Mount Lidgbird (31.56°S, 159.08°E; 777 m elevation) and Mount Gower (31.59°S, 159.074°E; 875 m elevation) (NSW Government Office of Environment and Heritage 2017). It is recorded primarily from sites on the north face of Mount Gower including 'Eddie's Cave', the southern precinct of 'Big Pocket', and the 'Black Face' and 'Grey Face' ridges of Mount Lidgbird, although it also occurs across other, less accessible patches between these sites (NSW Government Office of Environment and Heritage 2017). *Carmichaelia exsul* plants are scattered across cliff faces and rocky ridges at these sites generally from 400-600m elevation, generally occurring as single plants or in small patches (NSW Government Office of Environment and Heritage 2017). The maximum distance between Mount Gower and Mount Lidgbird sites is around 2 km (C. Stehn pers. comm. 2022).

Much of the habitat for the species is challenging to access, requiring difficult hikes or rock climbing, and some known sites are almost entirely inaccessible, particularly following landslips (Hutton 2005; NSW Government Office of Environment and Heritage 2016; Sheringham et al. 2020). As a consequence, monitoring sites are restricted to the few areas regularly accessible by foot, however likely habitat has been well documented, and range and population estimates are likely to be reliable (NSW Government Office of Environment and Heritage 2017; Sheringham et al. 2020).

Extent of Occurrence and Area of Occupancy

Extent of Occurrence (EOO) and Area of Occupancy (AOO) were calculated based on validated occurrence records drawn from Bionet and recent monitoring reports (NSW Government Office of Environment and Heritage 2017; NSW Government Saving our Species 2018, 2021a; Department of Planning and Environment, 2022). This yielded 53 records, however three of these points were excluded from further analysis as they gave only generalized georeferencing for Lord Howe Island. These points were from records over 100 years old (1898, 1915, 1920) and subsequently ascribed general coordinates for the island with no additional notes available to help locate the collection sites.

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EOO and AOO were estimated in GeoCAT (Bachman et al. 2011). Area of Occupancy (AOO) was calculated by overlaying 2 km x 2 km grid cells over the known occurrence and is the spatial scale of assessment recommended by IUCN (IUCN Standards and Petitions Committee 2022). Extent of Occurrence (EOO) is based on a minimum convex polygon enclosing all known occurrences of the species recorded in Bionet, the method of assessment recommended by the IUCN (2022).

AOO for *Carmichaelia exsul* is 16 km². Surveys since 2001 have detected *C. exsul* at a small number of sites in the Southern Mountains area of Lord Howe Island (NSW Government Office of Environment and Heritage 2017). As a consequence, the entire population of *C. exsul* occurs in an area that can be contained within four 2 km x 2 km grid squares, which is the smallest standard grid resolution recommended for assessments of AOO under the IUCN Standards and Petitions Committee (2022).

Carmichaelia exsul is restricted to a small number of tiny sites across Lord Howe Island, and as a result EOO (3.653 km²) is less than the estimate of AOO (16 km²). Where EOO is less than or equal to AOO then IUCN guidelines recommend EOO estimates be changed to be equal to AOO to ensure consistency with the definition of AOO as an area that fits within EOO (IUCN Standards and Petitions Committee 2022). As such, the EOO for *C. exsul* is also estimated as 16 km².

Consistent and ongoing vegetation surveys across Lord Howe Island means these estimates of EOO and AOO are likely to accurately reflect distribution of *Carmichaelia exsul* across Lord Howe Island and are appropriate for assessment under the IUCN (2022) criteria.

Population estimates

Surveys from 2017 to 2021 give a total population estimate of 200 plants, including both mature and juvenile individuals, and a population estimate of 110-140 mature individuals (NSW Government Saving our Species 2021a). This number is drawn from ongoing monitoring of seven plots (ranging from 5 x 5m to 15 x 15m) at five permanent monitoring sites. Selection of sites for ongoing monitoring is primarily determined by accessibility, but they are considered to provide a reliable representation of the broader population (NSW Government Office of Environment and Heritage 2017; NSW Government Saving our Species 2021a). The results from these plots are then extrapolated across the area over which *Carmichaelia exsul* is believed to occur to produce a total population estimate (NSW Government Office of Environment and Heritage 2017; NSW Government Saving our Species 2021a). The estimate for total mature individuals is based on a total population estimate of 200 from 2017 – 2021 surveys, where between 55-70% of individuals in the surveyed population were mature (NSW Government Saving our Species 2021a). Landslips in 2020/21 (two of which affected access but left the *Carmichaelia* intact, and one of which directly impacted a *Carmichaelia* site) meant that only 4/7 sites could be sampled, however there was no decline at sites where monitoring was possible, and the overall population was still estimated at around 200 individuals (NSW Government Saving our Species 2021a).

Sites are formally monitored every two years, and individuals are opportunistically monitored both inside and outside monitoring sites when possible (NSW Government Saving our Species 2021; NSW Government Office of Environment and Heritage

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2017; C. Stehn pers. comm. 2022). The choice of sites for ongoing monitoring is primarily determined by accessibility, but they are considered to provide a reliable representation of the broader population (NSW Government Office of Environment and Heritage 2017; NSW Government Saving our Species 2021a). All individuals in monitoring plots are counted, and measurements of population structure are recorded (NSW Government Office of Environment and Heritage 2017; NSW Government Saving our Species 2021a).

Surveys conducted for *Carmichaelia exsul* prior to 2017 were not systematic and were conducted at a subset of the sites (NSW Government Office of Environment and Heritage 2017). These surveys expanded the known sites for *C. exsul* but did not provide estimates of population, and therefore have not been used to estimate population trend for the species.

Ecology

Carmichaelia exsul is restricted to sunny, exposed, north and west facing cliff faces and ridges, generally between 400 and 600m elevation, below the volcanic mountain summits that support cloud forests (NSW Government Office of Environment and Heritage 2017). *Carmichaelia exsul* favours open, exposed sites usually without tree canopy cover, however they can tolerate more dense vegetation with some low canopy (C. Stehn pers. comm. 2022). This extremely steep habitat receives seepage moisture and experiences periodic landslips. *Carmichaelia exsul* shares general habitat and features of ecology with three other threatened plants from Lord Howe Island, *Geniostoma huttonii*, *Xylosma parvifolium* and *Coprosma inopinata*, along with more common species (Hutton 2001, 2005). These plants form dense, stunted communities less than one metre in height, of which *C. exsul* is a part (Hutton 2001, 2005; NSW Government Office of Environment and Heritage 2017).

During two decades of monitoring, *Carmichaelia exsul* has not been observed to colonise any adjacent habitat, and while it persists well at sites where it is already established, it appears to struggle to establish in the presence of other endemic or invasive species (C. Stehn pers. comm. 2022). Cliff-dwelling species like *C. exsul* are commonly specialised to exposed conditions, allowing plants to thrive on cliff faces and ridgelines (Caperta et al., 2014). However, rare and highly specialized species may also be less tolerant to changes in habitat or climate, which reduces their competitiveness with invasive and endemic generalist species in sub-optimal conditions (Caperta et al., 2014; Elizabeth, 2007).

Carmichaelia exsul is likely to be pollinated both by native dipteran insect species and introduced honeybees that are present on Lord Howe Island. In *Carmichaelia* species where pollinators have been identified all are insect pollinated with the exception of *C. williamsii*, which is bird pollinated and notable for its exceptionally large flowers, far larger than those of *C. exsul* (Heenan and de Lange 1999). The fruit of *C. exsul* is a thin flattened pod 12 mm long, with a persistent replum from which the 2 valves fall away, exposing a pale orange seed (Hutton 2001). This colour and shape is thought to promote seed dispersal by birds by mimicking a fleshy, palatable fruit (Thorsen et al., 2009).

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Given the very restricted range of *Carmichaelia exsul* it is unlikely that the population is severely fragmented, with pollinators likely able to access individuals across its very highly restricted range and birds likely able to disperse seed across suitable habitat.

Life History

There has been no formal study into life history in *Carmichaelia exsul*. *Carmichaelia* species appear to be relatively long-lived, with studies counting 20 or more growth rings in a range of *Carmichaelia* species from shrubs to trees, with only one exception to this relative longevity (*C. juncea*) (Gruner 2003). Given this general pattern of longevity in *Carmichaelia* it is likely that *C. exsul* is similarly long lived (20+ years).

It is unknown how long *Carmichaelia exsul* takes to reach maturity. While generally being long-lived, *Carmichaelia* species differ considerably in the time it takes for individuals to reach maturity. In their study into comparative ecology of *Carmichaelia*, Gruner (2003) observed that:

‘The time period needed to reach maturity...appears to vary considerably between the species. While some species have been observed to flower within the first (*C. juncea*, *C. curta*) or second year after germination (*C. kirkii*, *C. australis*; pers. obs.), *C. muritai* plants produce their first flowers only after ten years (J. Clayton-Greene, DoC Renwick, pers. comm.)’

Given the broad variation in age at maturity for *Carmichaelia* species it is not possible to make inferences as to the likely age at which *Carmichaelia exsul* becomes mature and able to reproduce. As a consequence, no estimates for generation time have been made for *C. exsul*.

Seed Viability

Carmichaelia exsul shows high long-term seed viability. Seeds collected from a specimen in cultivation outside Lord Howe Island and kept at room temperature were shown to still be viable after 22 years and had a germination rate of 96% (Grüner and Heenan 2001). Seed from other *Carmichaelia* species have been shown to persist in wild seedbanks for at least two years (Grüner and Heenan 2001; Gruner 2003). Surveys in 2020/21 noted large seed crops on several adult plants. With rodent eradication and weed control, respectively, reducing seed predation and competition pressure, a viable wild seedbank may provide an opportunity for the *C. exsul* population to recover in areas where threats are consistently managed, while the high viability of collected seed offers possibilities for *ex situ* conservation (NSW Government Saving our Species 2021a). Seed was collected from *C. exsul* in 2019/2020 and sent to the seed bank at the Australian Botanic Garden Mount Annan (NSW Government Saving our Species 2019).

Threats

Increasing hydrological deficit as a result of climate change

While there is broad uncertainty in the projected range and severity of climate impacts on Lord Howe Island, Auld and Leishman (2015) determined that there was evidence

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for increase in temperature and a decrease in overall rainfall on Lord Howe Island over the last 50 years, stating that:

“...sea level temperatures around Lord Howe Island have risen by some 0.6°C since 1940... average annual air temperature on Lord Howe Island is expected to rise (compared with 1990 levels) by $1.3 \pm 0.6^\circ\text{C}$ by 2030, although there is much uncertainty around such estimates...For annual rainfall, we found over the last 50 years there had been a decline of 31% (95% CL 4–79%)...Both minimum and maximum temperatures at sea level increased in the last 50 years...”

The majority of plants endemic to the Lord Howe group are reliant on high humidity and are threatened by an increasingly dry environment (Auld and Leishman 2015). A less humid environment will likely favour less specialised invasive weed species and reduce suitable habitat available to native species like *Carmichaelia exsul* (Auld and Leishman 2015). ‘Anthropogenic climate change’ is listed as a Key Threatening Process under the NSW Biodiversity Conservation Act (BC Act).

Cloud lift and resulting habitat loss is another effect of climate change that poses a direct threat to *Carmichaelia exsul*. Clouds form when air cools to dew point as a parcel of air rises vertically via convection, front and orographic (mountain) uplift, and many plants on Lord Howe Island depend on consistent and ongoing formation of cloud to provide the high humidity and moisture on which they depend (Auld and Leishman 2015). Increase in sea temperatures is likely to increase the altitude at which clouds form, increasing aridity at lower altitudes and pushing dependent species further towards the summit, dubbed the ‘lift-cloud-base hypothesis’ (Auld and Leishman 2015).

Cloud forests serve as a ‘bucket’, absorbing rain and atmospheric moisture at the summit which then flows down, providing available moisture for plant communities further down the slope (Foster 2001), including *Carmichaelia exsul* habitat. Cloud lift poses a direct threat to species that live in cloud forest at the summit of Mount Gower and Mount Lidgbird, as well as species such as *Carmichaelia exsul* that are found below the cloud line and receive moisture created by cloud formation at the summit. Ongoing increase in sea temperature, and associated cloud lift and aridity, is therefore likely to reduce the quality and availability of habitat for *C. exsul* in the future.

Carmichaelia exsul is confined to cliffs and ridges at relatively high elevations (~400-600 m), above which habitat is generally unsuitable, largely opening into plateaux dominated by dense vegetation, especially Gnarled Mossy Cloud Forest. (C. Stehn pers. comm. 2022). The general lack of adjacent exposed cliffs and ridgelines at higher elevations means that there is limited accessible habitat into which *C. exsul* can move as increasing aridity makes their current habitat less suitable (C. Stehn pers. comm. 2022). As a poor coloniser *Carmichaelia exsul* is likely to struggle to expand into any new habitat that may become available as aridity forces resident plant communities to higher elevations. Even if resident plant communities are pushed from habitat potentially suitable for *C. exsul*, components of these communities, like established trees or generalist weed species, are likely to persist and present an ongoing barrier to colonisation.

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The acute drought from 2018 to 2021 severely impacted multiple Lord Howe Island plant species and communities and demonstrated that drought is a severe and ongoing threat for species on Lord Howe Island (International Union for Conservation of Nature and Natural Resources 2020; NSW Government Saving our Species 2021b). Droughts across the Australian continent are becoming more severe as background climate becomes more arid (Abram et al. 2021), and this is likely to increase the threat drought poses to endemic Lord Howe Island species, including *Carmichaelia exsul*.

Landslips

Carmichaelia exsul is threatened by damage or destruction by landslips (NSW Government Saving our Species 2021a). The species is restricted to rocky ridgelines and exposed cliff faces, areas that are commonly susceptible to collapse and landslips on Lord Howe Island, particularly following heavy rain (NSW Government Saving our Species, 2021; C. Stehn pers. comms. 2022). Climate change may increase the likelihood and severity of sub-tropical storms on and around Lord Howe Island, posing an additional severe threat to plant communities towards the peaks of Mount Gower and Lidgbird (Auld and Leishman 2015). These storms may damage *Carmichaelia exsul* directly, or increase the likelihood of landslips as a result of heavy rain.

In 2020/21 landslips resulted in the loss of at least six individuals, although it is possible some of these plants persisted but could not be relocated because of the inaccessibility of the sites (NSW Government Saving our Species 2021a). These landslips also made surveys impossible at several sites and hinder ongoing monitoring (NSW Government Saving our Species 2021a). There is currently no way to prevent or mitigate the threat of landslips at sites where *C. exsul* is present (C. Stehn pers. comm. 2022).

Competition by Invasive Weeds

Invasive weeds pose a severe and ongoing threat to *Carmichaelia exsul* (Lord Howe Island Board 2016; NSW Government Office of Environment and Heritage 2017). Weeds encroach on the habitat of *C. exsul*, outcompeting standing plants for resources and space and inhibiting recruitment by reducing the likelihood *C. exsul* seeds will find sufficient space and resources to germinate (Lord Howe Island Board, 2016; T. Auld pers. comms. 2022). Of particular concern are *Ageratina adenophora* (Crofton Weed), *Lilium formosanum* (Formosan Lily), *Cenchrus clandestinus* (Kikuyu Grass), *Asparagus aethiopicus* (Ground Asparagus) and *Psidium cattleianum* var. *cattleianum* (Cherry Guava) (Lord Howe Island Board, 2016; T. Auld pers. comm. 2022). These weed species remain common across Lord Howe Island and threaten multiple endemic plants and communities, including *C. exsul* (Lord Howe Island Board, 2016; NSW Government Saving our Species, 2021; T. Auld pers. comm. 2022).

An ongoing, intensive weed control program started in 2004 and resulted in a decline in the number of mature weeds encroaching on habitat of *Carmichaelia exsul* (Lord Howe Island Board 2016; NSW Government Office of Environment and Heritage 2017). There has been a reduction of 90% in mature weed plants on Lord Howe Island since weed eradication efforts began, and in 2020/21 only 0.01% of weeds removed in the Southern Mountains region were mature (NSW Government Office of Environment and Heritage 2017; NSW Government Saving our Species 2021a).

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However, there is evidence that the overall number of juvenile weeds may be increasing. In 2020/21 63 weeds were controlled per hectare, compared to 43 per hectare in 2019/20 (NSW Government Saving our Species 2021a). This increase is possibly driven by drought and increasing aridity, with generalist weed species on Lord Howe Island likely more successful than endemics in changing environments, and by the removal of rats (discussed below) (Lord Howe Island Board 2016; NSW Government Saving our Species 2021b). The increase in juvenile weeds highlights the severe ongoing threat of weed infestation and ecosystem decline in the absence of effective control.

Increased weed pressure in the absence of rodents

Introduced rodents, in particular the ship rat (*Rattus rattus*) and house mouse (*Mus musculus*), have had a devastating effect on native flora and fauna of Lord Howe Island. Rats eat seeds and seedlings of many species and since their introduction following a shipwreck in 1918, ship rats have been the driving factor in the extinction of at least two Lord Howe Island plant species (Department of Environment and Climate Change (NSW) 2007). Historically, rodents have not been considered a severe direct threat to *Carmichaelia exsul* because of its inaccessible habitat, although browsing and fruit predation has been observed (Lord Howe Island Board 2017; C. Stehn pers. comms. 2022).

An extensive program of rodent eradication on the main island was undertaken in 2019 (Harper et al. 2020). This program appears to have been successful and rats and mice are likely to have been eradicated from the island. However, the program has not yet been officially declared successful and ongoing monitoring is in place, both for rodents and to quantify the benefits and/or ecosystem changes resulting from the pest eradication.

There are indications that rodent eradication has reduced predation pressure on weed populations and native vegetation. In the absence of rodents, weed populations may increase and spread, posing a more significant threat to *C. exsul* (NSW Government Saving our Species, 2021; C. Stehn pers. comms. 2022).

Root-rot, *Phytophthora cinnamomi*

Phytophthora cinnamomi is an introduced water mould (oomycetes) pathogen that has had a devastating effect on plant communities world-wide, causing catastrophic dieback in many species, and is listed as the Key Threatening Process 'Dieback caused by the root-rot fungus *Phytophthora cinnamomi*' on the EPBC Act. *Phytophthora cinnamomi* affects a huge variety of plants across families, including Fabaceae, and so may pose a considerable threat to *Carmichaelia exsul* (Government of South Australia Phytophthora Technical Group 2006; NSW Department of Environment and Climate Change 2008).

Phytophthora cinnamomi was detected in a small orchard on Lord Howe Island in 2003 and is now considered a resident threat on the island (Auld and Hutton 2004). It has so far been contained, however the movement of residents and tourists across the island risk its spread in the future.

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Assessment against IUCN Red List criteria

For this assessment it is considered that the survey of *Carmichaelia exsul* has been adequate and there is sufficient scientific evidence to support the listing outcome.

Criterion A Population Size reduction

Assessment Outcome: Data Deficient

Justification: There is insufficient data on generation length, historic population size, or population decline in *Carmichaelia exsul* to apply criterion A. Although *C. exsul* has been recorded on Lord Howe Island for over 100 years, targeted surveys for the species have only been undertaken since 2001, and formal ongoing monitoring began 2017. As a result, there is insufficient data on historic range, population size, and life history to describe historic changes in population size.

Criterion B Geographic range

Assessment Outcome: Critically Endangered under Criterion B1ab(iii,v)

Justification: *Carmichaelia exsul* is restricted to a small number of cliffs and rocky ridges in the Southern Mountains region. As a result, EOO for *C. exsul* is 16 km², below the threshold for Critically Endangered for Criterion B1 (EOO <100 km²). AOO (16 km²) is also met at EN for criteria B2 (<500km).

In addition to these thresholds, at least two of three other conditions must be met. These conditions are:

- a) The population or habitat is observed or inferred to be severely fragmented or there is 1 (CR), ≤5 (EN) or ≤10 (VU) locations.

Assessment Outcome: Met for Critically Endangered (1 location)

Justification: *Carmichaelia exsul* is only found at one location, defined by the threat of competition from weeds, which appears to be exacerbated by increasing water deficit due to climate change and removal of rodents. Being restricted to a very small area of rocky ridge and cliff in the Southern Mountain's region of Lord Howe Island (AOO/EOO = 16 km²), means that the most serious plausible threats are highly likely to affect *C. exsul* across its entire range and cause decline in habitat extent or quality for the entire population. There is no evidence that *C. exsul* is severely fragmented.

- b) Continuing decline observed, estimated, inferred, or projected in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) area, extent and/or quality of habitat; (iv) number of locations or subpopulations; (v) number of mature individuals.

Assessment Outcome: Sub-criterion met – Continuing decline is inferred in (iii) area, extent and/or quality of habitat and (v) number of mature individuals.

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Justification: Observed and projected reduction in rainfall and humidity driven by climate change is inferred to reduce the quality of the habitat of *Carmichaelia exsul*. The species is restricted to cliff faces and rocky ridges in the Southern Mountains region, generally between 400 and 600 m elevation, and has not been observed to colonise new sites (NSW Government Office of Environment and Heritage 2017). This habitat is likely to become increasingly arid and less suitable for *C. exsul* as rainfall continues to decline as projected, and more susceptible to the threat of encroachment by generalist weed species. In the absence of rodents, weed populations are projected to increase and spread, posing a significant threat to *C. exsul*. *Carmichaelia exsul* does not compete well with endemic or introduced species and so is unlikely to successfully colonise new habitat if it becomes available as vegetation communities on peaks shift in response to changing moisture availability.

The species is also threatened by damage or destruction by landslips, and in 2020/21 landslips resulted in the observed loss of at least six individuals. This threat is predicted to increase under climate change through an increase in the likelihood and severity of subtropical storms.

c) Extreme fluctuations.

Assessment Outcome: Not Met

Justification: There is no evidence for extreme population fluctuations in *Carmichaelia exsul*.

Criterion C **Small population size and decline**

Assessment Outcome: Critically Endangered under Criterion C2a(ii)

Justification: The population estimate for mature individuals is 110-140. This number is drawn from ongoing monitoring of seven plots at five permanent monitoring sites, the results of which are extrapolated across all sites at which *Carmichaelia exsul* is known to occur to produce a total population estimate. The total population meets the threshold for Critically Endangered (<250). Listing under criterion C also requires either condition C1 or C2 to be met. Data is deficient for assessment against condition C1, but there is an observed and inferred continuing decline in number of mature individuals as a result of landslips.

At least one of two additional conditions must be met. These are:

- C1. An observed, estimated or projected continuing decline of at least: 25% in 3 years or 1 generation (whichever is longer) (CR); 20% in 5 years or 2 generations (whichever is longer) (EN); or 10% in 10 years or 3 generations (whichever is longer) (VU).

Assessment Outcome: Data Deficient

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Justification: There is no available data on historic population size or decline in *Carmichaelia exsul*. Although *C. exsul* has been recorded on Lord Howe Island for over 100 years, intensive surveys for the species have only been recorded since 2001 and formal ongoing monitoring began in 2017. As a result, there is insufficient data on historic range or population size to quantify changes in population size.

C2. An observed, estimated, projected or inferred continuing decline in number of mature individuals.

Assessment Outcome: Criterion met.

Justification: There has been an observed decline in the number of individuals as a result of damage or destruction by landslips. In 2020/21 landslips resulted in the observed loss of at least six individuals, and this threat is predicted to increase under climate change through an increase in the likelihood and severity of subtropical storms.

In addition, at least 1 of the following 3 conditions:

- a (i). Number of mature individuals in each subpopulation ≤ 50 (CR); ≤ 250 (EN) or ≤ 1000 (VU).

Assessment Outcome: Met for Endangered (≤ 250 in each subpopulation)

Justification: The population estimate for mature individuals is 110-140. Whilst plants occur in different patches, all *Carmichaelia exsul* plants on Lord Howe Island are likely to comprise the one subpopulation.

- a (ii). % of mature individuals in one subpopulation is 90-100% (CR); 95-100% (EN) or 100% (VU)

Assessment Outcome: Met for Critically Endangered (at least 90% of mature individuals in one subpopulation)

Justification: All *Carmichaelia exsul* individuals occur in a single subpopulation at a single location, restricted to cliffs and ridgelines in the Southern Mountains region of Lord Howe Island.

- b. Extreme fluctuations in the number of mature individuals

Assessment Outcome: Not Met

Justification: There is no evidence for extreme fluctuations in the population of *Carmichaelia exsul*.

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Criterion D **Very small or restricted population**

Assessment Outcome: Met for Endangered (<250 mature individuals)

Justification: The population estimate for mature individuals is 110-140.

To be listed as Vulnerable under D, a species must meet at least one of the two following conditions:

D1. Population size estimated to number fewer than 1,000 mature individuals

Assessment Outcome: Met for Endangered D1 (<250 mature individuals)

Justification: The total population estimate for mature individuals is 110-140.

D2. Restricted area of occupancy (typically <20 km²) or number of locations (typically <5) with a plausible future threat that could drive the taxon to CR or EX in a very short time.

Assessment Outcome: Not Met

Justification: While the population is only known from a single location with a small total AOO (16 km²), there is no clear future threat to *Carmichaelia exsul* that would contribute to the extinction of the species in a very small time.

Criterion E **Quantitative Analysis**

Assessment Outcome: Data deficient

Justification: No population viability analysis is available for *Carmichaelia exsul*.

Conservation and Management Actions

Carmichaelia exsul is currently listed on the NSW *Biodiversity Conservation Act 2016* and a conservation project has been developed by the NSW Department of Planning and Environment under the *Saving our Species* program. The conservation project identifies priority locations, critical threats and required management actions to ensure the species is extant in the wild in 100 years. *Carmichaelia exsul* sits within the site-managed management stream of the SoS program.

Activities to assist this species currently recommended by the SoS program include:

Habitat loss, disturbance and modification

- Broad-scale weed control continuing across the Southern Mountains region under the Lord Howe Island Weed Management Strategy.
- Ongoing monitoring for rodent re-invasion following the completion of the Lord Howe Island Rodent Eradication Project.

Ex situ conservation

- Seeds collected from multiple individuals/locations and over several collection events.

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Survey and monitoring

- Permanently tag and monitor accessible *Carmichaelia exsul* individuals and record details of height class, age structure and reproductive status
- Continue monitoring trends in weed invasion
- Identify and estimate *Carmichaelia exsul* populations outside of monitoring sites

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APPENDIX 1

Assessment against *Biodiversity Conservation Regulation 2017* criteria

The Clauses used for assessment are listed below for reference.

Overall Assessment Outcome:

Carmichaelia exsul was found to be Critically Endangered under Clause 4.3 (a)(d)(e i,iii) and Endangered under 4.5 (b).

Clause 4.2 – Reduction in population size of species

(Equivalent to IUCN criterion A)

Assessment Outcome: Data Deficient

(1) - The species has undergone or is likely to undergo within a time frame appropriate to the life cycle and habitat characteristics of the taxon:			
	(a)	for critically endangered species	a very large reduction in population size, or
	(b)	for endangered species	a large reduction in population size, or
	(c)	for vulnerable species	a moderate reduction in population size.
(2) - The determination of that criteria is to be based on any of the following:			
	(a)	direct observation,	
	(b)	an index of abundance appropriate to the taxon,	
	(c)	a decline in the geographic distribution or habitat quality,	
	(d)	the actual or potential levels of exploitation of the species,	
	(e)	the effects of introduced taxa, hybridisation, pathogens, pollutants, competitors or parasites.	

Clause 4.3 - Restricted geographic distribution of species and other conditions (Equivalent to IUCN criterion B)

Assessment Outcome: Critically Endangered under Clause 4.3 (a) (d) (e i, iii)

The geographic distribution of the species is:			
	(a)	for critically endangered species	very highly restricted, or
	(b)	for endangered species	highly restricted, or
	(c)	for vulnerable species	moderately restricted,
and at least 2 of the following 3 conditions apply:			
	(d)	the population or habitat of the species is severely fragmented or nearly all the mature individuals of the species occur within a small number of locations,	
	(e)	there is a projected or continuing decline in any of the following:	
		(i)	an index of abundance appropriate to the taxon,
		(ii)	the geographic distribution of the species,
		(iii)	habitat area, extent or quality,
		(iv)	the number of locations in which the species occurs or of populations of the species,
	(f)	extreme fluctuations occur in any of the following:	

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	(i)	an index of abundance appropriate to the taxon,
	(ii)	the geographic distribution of the species,
	(iii)	the number of locations in which the species occur or of populations of the species.

Clause 4.4 - Low numbers of mature individuals of species and other conditions (Equivalent to IUCN criterion C)

Assessment Outcome: Critically Endangered under Clause 4.4 (a)(e i, ii B)

The estimated total number of mature individuals of the species is:			
	(a)	for critically endangered species	very low, or
	(b)	for endangered species	low, or
	(c)	for vulnerable species	moderately low,
and either of the following 2 conditions apply:			
	(d)	a continuing decline in the number of mature individuals that is (according to an index of abundance appropriate to the species):	
	(i)	for critically endangered species	very large, or
	(ii)	for endangered species	large, or
	(iii)	for vulnerable species	moderate,
	(e)	both of the following apply:	
	(i)	a continuing decline in the number of mature individuals (according to an index of abundance appropriate to the species), and	
	(ii)	at least one of the following applies:	
		(A)	the number of individuals in each population of the species is:
		(I)	for critically endangered species extremely low, or
		(II)	for endangered species very low, or
		(III)	for vulnerable species low,
		(B)	all or nearly all mature individuals of the species occur within one population,
		(C)	extreme fluctuations occur in an index of abundance appropriate to the species.

Clause 4.5 - Low total numbers of mature individuals of species (Equivalent to IUCN criterion D)

Assessment Outcome: Endangered under Clause 4.5 (b).

The total number of mature individuals of the species is:			
	(a)	for critically endangered species	extremely low, or
	(b)	for endangered species	very low, or
	(c)	for vulnerable species	low.

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Clause 4.6 - Quantitative analysis of extinction probability (Equivalent to IUCN criterion E)

Assessment Outcome: Data deficient

The probability of extinction of the species is estimated to be:			
	(a)	for critically endangered species	extremely high, or
	(b)	for endangered species	very high, or
	(c)	for vulnerable species	high.

Clause 4.7 - Very highly restricted geographic distribution of species–vulnerable species

(Equivalent to IUCN criterion D2)

Assessment Outcome: Not Met

For vulnerable species,	the geographic distribution of the species or the number of locations of the species is very highly restricted such that the species is prone to the effects of human activities or stochastic events within a very short time period.
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